Claims

1. A computer-based method for locating one or more landmarks using an MR image of a brain, the method including the following automatic steps:

(a) identifying a region of interest with a plane of the MR image, the plane containing the landmark(s);

(b) binarising the plane of the MR image into foreground and background voxels based on at least one threshold selected using anatomical knowledge;

(c) identifying a set of object voxels from the foreground voxels, the set of object voxels excluding voxels which were only classified as foreground voxels due to proximity of cortical and non-cortical structures;

(d) identifying object voxels from the background voxels due to the partial volume effect and/or morphological erosion/opeing; and

(e) identifying the one or more landmarks using the object voxels.

2. A method according to claim 1 in which the step of identifying the object voxels is performed in two stages:

(i) morphological processing which excludes foreground voxels which may not be object voxels, and

(ii) restoring voxels which have been incorrectly excluded in the morphological processing.

3. A method according to claim 2 in which the step of identifying the object voxels further includes applying anatomical knowledge to identify the object voxels.

4. A method according to claim 3 in which the anatomical knowledge is knowledge about the expected shapes of cortical and/or non-cortical structures.

5. A method according to any preceding claim in which the threshold is selected by the steps of:

(i) using prior knowledge about the image to derive an intensity range of voxels in the said region of interest; and

(ii) obtaining a frequency distribution of the intensities within the said intensity range of voxels within the said region of interest; and

(iii) using the said frequency distribution to derive an intensity threshold.

6. A method according to claim 5 in which the intensity threshold is selected by minimising a function which is a sum of the variances of the intensities below and above the threshold.

7. A method according to claim 6 in which said function is a weighted sum defined based on two constants W_1 and W_2.

8. A method according to claim 7 in which, labelling the possible values of voxel intensity by an integer index i and their respective frequencies by $h(i)$, and writing the lower and upper intensities respectively as r_{low} and r_{high}, the weighted sum is given by

$$\theta_{RCLWV}(W_1,W_2) = \max_{r_k}(\Pr(C_1)D(C_1)W_1 + \Pr(C_2)D(C_2)W_2),$$

where $Pr(.)$ denotes the class probability $(\Pr(C_1) = \sum_{i=r_{low}}^{r_k} h(i)$ and $\Pr(C_2) = \sum_{i=r_k+1}^{r_{high}} h(i))$,, and $D(C_1)$ and $D(C_2)$ are given by:

$D(C_1) = (\mu_0 - \mu_T)^2$ and $D(C_2) = (\mu_1 - \mu_T)^2$, where $\mu_T = \sum_{i=r_{low}}^{r_{high}} i \times h(i)$,

$\mu_0 = \sum_{i=r_{low}}^{r_k} i \times h(i)$ and $\mu_1 = \sum_{i=r_k+1}^{r_{high}} i \times h(i)$.

9. A method according to any of claims 1 to 8 in which the set of steps (a) to (e) are performed repeatedly, in each set of steps identifying at least one corresponding landmark.

10. A method according to any of claims 1 to 8 in which the set of steps (a) to (d) are performed to locate the A, P, L and R landmarks,

in step (a) the region of interest being defined within the AP plane; and

in step (e) the most anterior and most posterior of the object voxels being taken respectively as the vertical coordinates of the A and P landmarks respectively, and the extreme horizontal components of the object voxels are taken as the horizontal coordinates of the L and R landmarks respectively.

11. A method according to claim 10 in which in step (c):

at least one morphological opening operation on the binarized image obtained in step (b) is performed; and

one or more voxels of the image(s) obtained by the opening operation(s) are classified as object voxels or otherwise according to at least one criterion based on distances in the image(s) obtained by the opening operation(s) and anatomical knowledge.

12. A method according to claim 11 in which, prior to the classification, a maximum distance maxDSkull is obtained from a distance transform of the ROI.

13. A method according to claim 11 in which, in the classifiction:

object voxels far from the skull lost due to the morphological opening operation(s) are restored

object voxels around the boundaries lost due to the morphological opening operation(s) are restored; and

object voxels lost due to the partial volume effect are restored.

14. A method according to any of claims 1 to 8 in which the set of steps (a) to (d) are performed to obtain the S landmark,

in step (a) the region of interest being defined within a virtual plane obtained from the VPC coronal slice;

in step (e) the position of the S landmark is the most superior point within the object voxels.

15. A method according to claim 14 in which in step (c):

at least one morphological opening operation on the binarized image obtained in step (b) is performed;

one or more voxels of the image(s) obtained by the morphological opening operation(s) which are not presently classified as object voxels are re-classified as object voxels if they are one of the eight immediate neighbours of an object voxel and if their intensity value in the MR image is higher than a value defined in relation to a second threshold.

16. A method according to any of claims 1 to 8 in which the set of steps (a) to (d) is performed to identify the I landmark,

in step (a) the region of interest being defined within the VAC plane;

in step (e) the I landmark being defined as the most inferior point within the object voxels.

17. A method according to claim 16 in which the threshold is obtained during a preceding process according to claim 1 of locating the S landmark.

18. A method according to claim 16 or claim 17 in which, in step (c), (i) at least one morphological opening operation and/or (ii) at least one seeding operation, are performed on on the binarized image obtained in step (b).

19. A method according to claim 18 in which, in step (c), one or more voxels of the image(s) obtained by the morphological opening operation(s) which are not presently classified as object voxels are re-classified as object voxels if they are one of the eight immediate neighbours of an object voxel and if their intensity value in the MR image is higher than a value defined in relation to a second threshold.

20. A method according to claims 16 to 19 in which the left and right halves of the brain are treated separately, and the object voxels used to obtain the location of the I landmark relate to a selected half of the brain, the selected half of the brain having been selected based on a predefined criterion.

21. A system for locating one or more landmarks using an MR image of a brain, the system including:

an interface to receive data encoding the MR image; and

a processor arranged to perform the following steps:

(a) identifying a region of interest with a plane of the MR image, the plane containing the landmark(s);

(b) binarising the plane of the MR image into foreground and background voxels based on at least one threshold selected using anatomical knowledge;

(c) identifying a set of object voxels from the foreground voxels, the set of object voxels excluding voxels which were only classified as foreground voxels due to proximity of cortical and non-cortical structures;

(d) identifying object voxels from the background voxels due to the partial volume effect and/or morphological erosion/opeing; and

(e) identifying the one or more landmarks using the object voxels.